Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz	)	GN Docket No. 17-183
	)	

COMMENTS OF NOKIA

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October 2, 2017

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Nokia respectfully submits these Comments in response to the Commission's Notice of Inquiry ("*NOI*") seeking comment on Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz.[1]

I. INTRODUCTION AND SUMMARY

Nokia is an innovation powerhouse, offering unparalleled leadership in the technologies that connect people and things. Nokia is leveraging its strengths to create a new type of network that is intelligent, efficient, and secure, and which will serve as a critical enabler of many capabilities and use cases associated with the Internet of Things (IoT). We are weaving together the networks, data, and device technologies to create the universal fabric of our connected lives.

Nokia brings together, in one company, mobile broadband with fixed line access, and the underlying IP routing and optical technology that connects them. Nokia has made pioneering advancements in reducing the footprint of mobile base station infrastructure, from compact yet full power macro sites down to the full range of small cell solutions, which are expected to be critical to enabling 5G deployment and IoT. Nokia offers the industry's most

[1] *Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz,* Notice of Inquiry, GN docket No. 17-183, FCC 17-104 (rel. Aug. 3, 2017) (*"NOI").*

comprehensive portfolio of services for integrating heterogeneous networks ("HetNets"), encompassing analysis, optimization, deployment, and management. Critical to its perspective regarding the spectrum bands considered in this proceeding, Nokia is a leading vendor in fixed microwave equipment, including being a major vendor to the largest fixed service licensees in the 6 GHz band.

Nokia applauds the Commission's global leadership in spectrum policy, and urges the Commission to move forward to allocate mid-band spectrum for innovative terrestrial use without delay. After years focusing mostly on low-band and high-band opportunities, this proceeding fills a conspicuous gap that will be critical to the roll-out of 5G throughout the country.

Nokia has focused for years on the 3.7-4.2 GHz band as the most favorable mid-band spectrum range to introduce 5G services in the U.S. The major incumbent in the band, Fixed Satellite Services (FSS), has seen a consistent, and steep decline in use over time. As described below, alternative technologies (such as fiber) and higher spectrum bands for FSS are increasingly preferred over the 3.7-4.2 GHz band. The licensing of facilities that no longer exist and reservation of far wider spectrum blocks than are actually used (attributed to the Commission's "full band, full arc" policy), further demonstrate that FSS is not intensively using the band. This is key to 3.7-4.2 GHz being a prime candidate for essentially unencumbered, true 5G capabilities.

Nokia recommends a licensing framework and technical rules for 5G services in the band that are more typical of prior nationwide deployments. For example, we recommend longer terms, larger geographic areas and higher power levels than recently adopted for the 3.5 GHz band.

Nokia does not oppose review of the 5.925-6.425 GHz and 6.425-7.125 GHz bands, but has concerns regarding the technical feasibility of introducing new services into those bands. Nokia is a major vendor for terrestrial Fixed Services (FS) throughout the upper and lower portions of the 6 GHz, which is a thriving business and important component to current generation communications as well as 5G. Any new use of the band must not cause interference into incumbent systems. Nokia therefore urges that, beyond legal obligations prohibiting interference (for example, the obligations set forth in Part 15 governing unlicensed operations), the Commission should not authorize new services in the upper or lower 6 GHz range until it first explores mitigation techniques and real-world engineering analysis to ensure any proposed operations will not cause harmful interference to fixed terrestrial services.

II. MID-BAND SPECTRUM IS CRITICAL FOR 5G ROLL-OUT IN THE UNITED STATES

The Commission leads the world in innovative spectrum policies, recently bolstering the amount of low-band spectrum with the first-of-its-kind 600 MHz incentive auction and then making almost 11 GHz of high-band spectrum available for flexible use, with more high-band spectrum being considered in its "Spectrum Frontiers" Further Notice of Proposed Rulemaking. Nokia agrees that "sound spectrum policy necessitates that [the Commission] now begin exploring new opportunity for flexible broadband use in the mid-band frequencies."[2] As the Commission points out:

> The combination of favorable propagation characteristics of the mid-band frequencies (as compared to bands above 24 GHz) and the opportunity for additional channel bandwidth (as compared to bands below 3.7 GHz), could make many of these mid-band frequencies well-suited for next generation wireless services.[3]

[2] *NOI* at ¶ 6.
[3] *Id.* ¶ 6.

Nokia especially supports the Commission's initial focus on the 3.7-4.2 GHz band for this Notice of Inquiry as low-hanging fruit for unlocking mid-band spectrum. For years, Nokia has actively advocated for opening the 3.7-4.2 GHz and the 3.1-3.55 GHz portions of the 3 GHz band for licensed terrestrial mobile broadband services. When combined with the 3.5-3.7 GHz band, those bands would provide more than 1 GHz of contiguous spectrum for mobility.

While we see substantial benefits to unlocking the full 3 GHz band, Nokia supports the Commission's initial inquiry on the 3.7-4.2 GHz portion of the band, as it is a non-Federal band and may have a shorter timeline to deployment than the lower portion of the band, which does have a Federal allocation. The 3.7-4.2 GHz range has strong potential for innovative wireless applications for several reasons:

Favorable propagation characteristics: The 3.7-4.2 GHz band has similar propagation characteristics as the adjacent 3.55-3.7 GHz band (3.5 GHz band), which the Commission already recently allocated for wireless broadband applications.[4]
The 3.7-4.2 GHz range has similar characteristics but even more promise for 5G services, based on greater bandwidth. Unlike the incumbent (predominantly Federal Government) uses that remain in the 3.5 GHz band, there is greater opportunity in the 3.7-4.2 GHz band to minimize encumbrances, thus creating a "cleaner" interference environment for 5G terrestrial deployments.

Adjacent to terrestrial use at 3.55-3.7 GHz range. As noted above, the 3.7-4.2 GHz range is just above the 3.55-3.7 GHz range and, when combined, can provide 650 MHz of contiguous spectrum that could enable extreme broadband delivery.

[4] *See Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band,* Report and Order and Second Further Notice of Proposed Rulemaking, GN Docket No. 12-354, FCC 15-47 (rel. April 17, 2015).

Global harmonization. The 3.55-4.2 GHz range is also being considered in other regions and countries for 5G and has a potential to become a globally harmonized range. For instance, on September 14, 2016, the European Commission published its 5G action plan which mentions that the "3.5 GHz band seems to offer high potential to become a strategic band for 5G launch in Europe."[5] The 3.5 GHz and 4 GHz ranges are also being considered in Japan and China.[6] 3GPP is specifying a 5G New Radio (NR) band that covers 3.3-4.2GHz range. Spectrum harmonization helps to achieve economies of scale, enables global roaming, reduces equipment design complexity and improves spectrum efficiency.[7] All of this ultimately reduces costs for consumers. In particular, device costs are a significant issue as widely supported spectrum bands and channels can lower the crucial radio frequency (RF) component costs. Harmonization also aids in addressing cross border coordination.

Nokia is part of a chorus of voices that agree exploration of this band would serve the public interest. For example, the Commission's Technological Advisory Council (TAC) Advanced Sharing Working Group recommended that the Commission consider 3.7-4.2 GHz for future sharing.[8] There is also support for legislation promoting the 3 GHz range. The MOBILE NOW Act (S.19) includes mandates to study the potential of the 3.1-3.55 GHz and 3.7-4.2 GHz bands. MOBILE NOW has passed the Senate and awaits consideration in the House.

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[5] *See* 5g for Europe, Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions, *5G for Europe: An Action Plan*, Sept. 16, 2016, available at https://ec.europa.eu/transparency/regdoc/rep/1/2016/EN/1-2016-588-EN-F1-1.PDF.

[6] *See Asia gets busy with latest 5G projects in Japan and China*, Mobile Europe, Nov. 9, 2016, available at http://www.mobileeurope.co.uk/press-wire/asia-gets-busy-with-latest-5g-projects-in-japan-and-china.

[7] *See* Document 5D/246-E, Canada's input to ITU-R WP 5D, "Technical perspective on benefits of spectrum harmonization for mobile services and IMT," 23 January 2013.

[8] *See* Technical Advisory Council, Federal Communications Commission, Summary of Meeting, Sept. 23, 2014, available at https://transition.fcc.gov/bureaus/oet/tac/tacdocs/meeting92314/TACMeetingSummary9-23-14.pdf.

Nokia also does not oppose the Commission's study of more intensive use of the of the 5.925-6.425 GHz and 6.425-7.125 GHz bands. However, as a major equipment vendor for incumbent fixed terrestrial services, we are concerned whether new uses could be introduced without causing harmful interference into those incumbent services.

III. THE 3.7 GHZ BAND IS THE KEY MID-BAND SPECTRUM RANGE FOR NEAR-TERM TERRESTRIAL 5G THROUGHOUT THE U.S.

Nokia and others in the industry have reviewed the Commission's licensing database, satellite spectrum usage trends and technology trends that demonstrate that Fixed Satellite operations in the 3.7-4.2GHz band are declining and generally overstated. The following sections discuss those trends that demonstrate that the 3.7 GHz band is a prime mid-band candidate for transitioning from satellite use to a band dedicated exclusively to terrestrial flexible uses.

A. Satellite Use of the 3.7 GHz Band Is in Decline, and the Commission's Database is Rife with Errors that Overstate Earth Station Use

Nokia has thoroughly analyzed the satellite Fixed Earth Stations (FESs) that have been registered in the Commission's International Bureau Filing System (IBFS) database. Our analysis has revealed that both the number of existing FESs and the number of grants obtained to

install new ones have been constantly declining over time. *See* Figure 1.

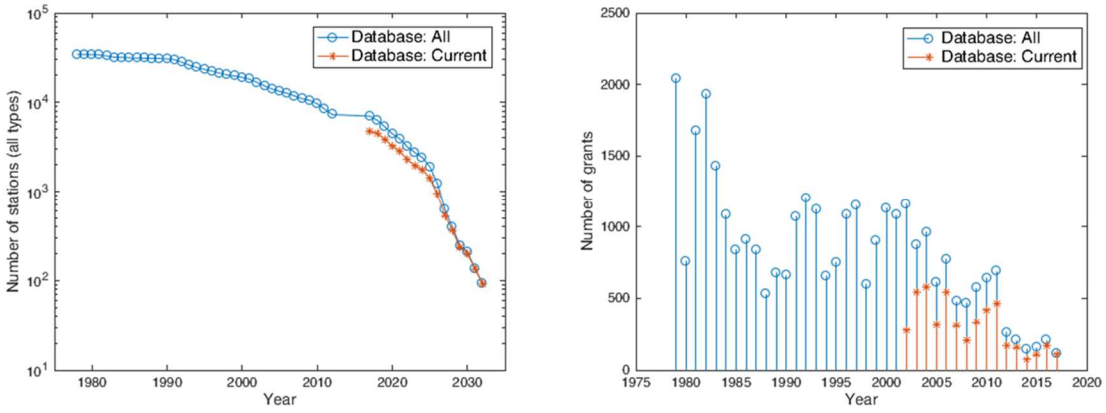

Figure 1. The number of earth stations, of different types, has significantly decreased since the 1980s (left). Similarly, the number of new grants is also falling (right), showing overall that the mid-band 3.7-4.2GHz is likely underutilized currently.[9]

Nokia understands that the trend away from the 3.7 GHz band can be attributed in large part to migration to other spectrum bands as well as a trend away from wireless altogether onto increasingly ubiquitous fiber technologies. For example, many licensees are moving to higher frequency bands, e.g., Ku-band, as more bandwidth is available to support high-resolution content distribution, and dishes are cheaper due to their smaller antenna size. For this reason, the mid-band spectrum between 3.7 GHz and 4.2 GHz appears to be underutilized with decreasing usage by incumbent FSS operators, further making the case to allow cellular services to exploit this spectrum and enable next-generation 5G networks for additional much needed network coverage and capacity in U.S. and worldwide.

Nokia respectfully submits that even these declining numbers found in the Commission's licensing database overstate the actual number of earth stations in operation in

[9] The Commission's database includes two ways to view the data: "All" and "Current." The "Current" view appears to be more accurate, but we included the "All" view as well to provide a larger dataset going back further in time before the "Current" view is available. In either view, the downward trend is clear.

these frequencies. The record in prior Commission proceedings demonstrates that about 30 percent of FSS earth stations licensed in the IBFS database simply do not exist.[10] On behalf of FWCC, Nokia conducted a random sampling of 300 C-band earth stations and found that 27 percent did not exist.[11] These earth stations may never have been built or, in several cases, we found photographic evidence on Google Earth that the earth stations *were* built, but were later dismantled (even the buildings on which they were mounted no longer exist) but left on the books. It appears some earth station licenses were *renewed* despite having previously been dismantled. In a much larger sample, the Broadband Access Coalition presented similar results in reviewing Commission records versus visual evidence, finding that no satellite facility matched the licensed coordinates in many cases.[12]

In sum, FSS use of the 3.7-4.2 GHz band has been in steady decline and is over-represented in the Commission's database. This decline in use, and the availability of alternative transmission options for FSS systems, make the band a great candidate for re-allocation for terrestrial 5G use.

B. The Commission's Special Treatment for Satellite Spectrum Coordination ("Full-Band, Full Arc") Overstates Current FSS Use

The NOI recognizes a problem previously brought to the Commission in the 3.7-4.2 GHz band and other bands shared between FS and FSS.[13] Specifically, under the current practice of "full-band, full-arc" coordination, FSS licensees are given the right to reserve a full

[10] *See* Broadband Access Coalition, Petition for Rulemaking, RM-11791, at 23 (filed June 21, 2017) ("BAC Petition"); FWCC Letter to FCC, Request for Audit of Licensed Satellite Earth Stations in Bands Shared with the Terrestrial Fixed Service, at 23 (filed Sept. 30, 2016) ("FWCC 2016 Audit Request").
[11] *See* FWCC 2016 Audit Request at 3.
[12] BAC Petition at 23.
[13] *NOI* at ¶ 17.

500 MHz of spectrum even if the licensee needs only a small fraction of that amount.[14] Contrary to this practice of "full band" coordination rights, it is typical for each earth station to access just one transponder on one satellite at any given time. For example, Associated Press (the largest earth station licensee in the band totaling 975 earth stations), is using only 23 MHz for each of these earth stations in a very stable and specific part of the band, between 3700 and 3800 MHz.[15]

Not only are about 30% of the earth station licenses not transmitting at all (i.e., as discussed above, they lack underlying facilities), there are many facilities in operation that are protected for a full 500 MHz while using less than 10 percent of that amount. All of these factors paint a picture of modest and declining FSS use, in a band that could be more intensely used by flexible terrestrial services.

With respect to "full arc," the FSS operators often claim communications with all points in the geostationary arc, even though many dishes stay pointed at the same satellite for years. Many dishes are even bolted in place and cannot be easily repointed.

We also note that earth station operators typically claim to require tight interference protections such as -129 dBm/MHz recently adopted in Part 96 rules. These criteria were self-derived by the FSS industry at the ITU decades ago, with little or no consideration of other services, and modern spectrum use and management. It is also to be noted that many FSS sites are surrounded by foliage and other obstacles providing additional protection from terrestrial interference. Such attenuation should be considered when determining the potential interference into FSS earth stations from terrestrial systems.

[14] Fixed Wireless Communications Coalition, Inc., Petition for Rulemaking, RM-11778, at 1 (filed Oct. 11, 2016) ("FWCC Petition").
[15] *See* BAC Petition at 22 and n.42.

C. The Commission Should Clear the 3.7-4.2 GHz Band of Satellite Service

Nokia has studied the coexistence of 5G systems with FESs in the 3.7-4.2 GHz spectrum. For accurate simulation results, we have used the information of existing FESs, i.e., their locations, heights, and antenna specifications. Specifically, we studied the potential 5G downlink and 5G uplink interference on FESs that are located in the Chicago Loop (see Figure 2), representing a dense urban area which is a prime target for 5G deployments.

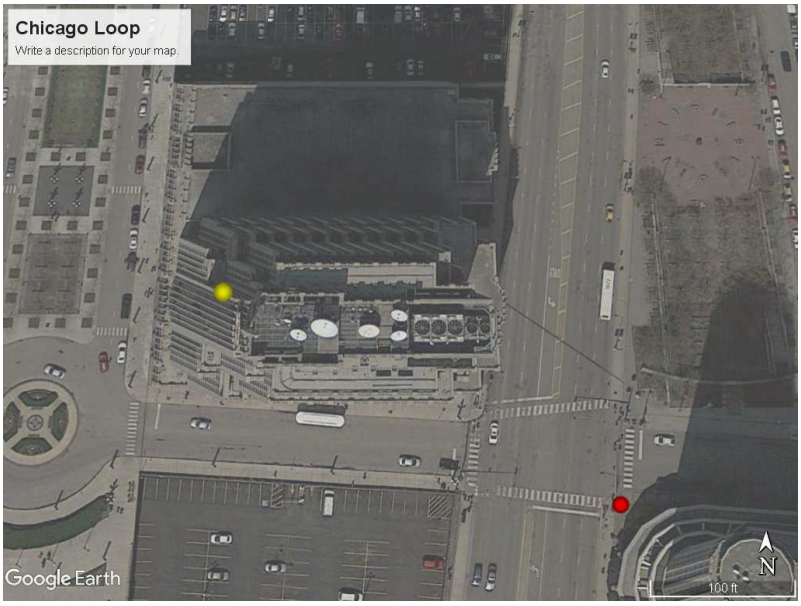

Figure 2. Example of satellite FESs on buildings in the Chicago loop

The model considers the 3GPP-recommended 5G new radio (NR) channel model as well as the actual building layout of the Chicago Loop. As for the FSS antenna patterns, we consider the pattern that meets the Commission's regulations in terms of radiated power for a given off-axis angle. The 5G base stations (gNBs) are deployed at street-corners, and user equipment terminals (UEs) are assumed to be randomly distributed in space. Figure 3 shows the layout of our system. We evaluate the aggregate uplink (i.e., from UEs towards FESs) as well as

the aggregate downlink (i.e., from gNBs) into FESs when the 5G system and the FESs are using the same spectrum blocks (co-channel operation).

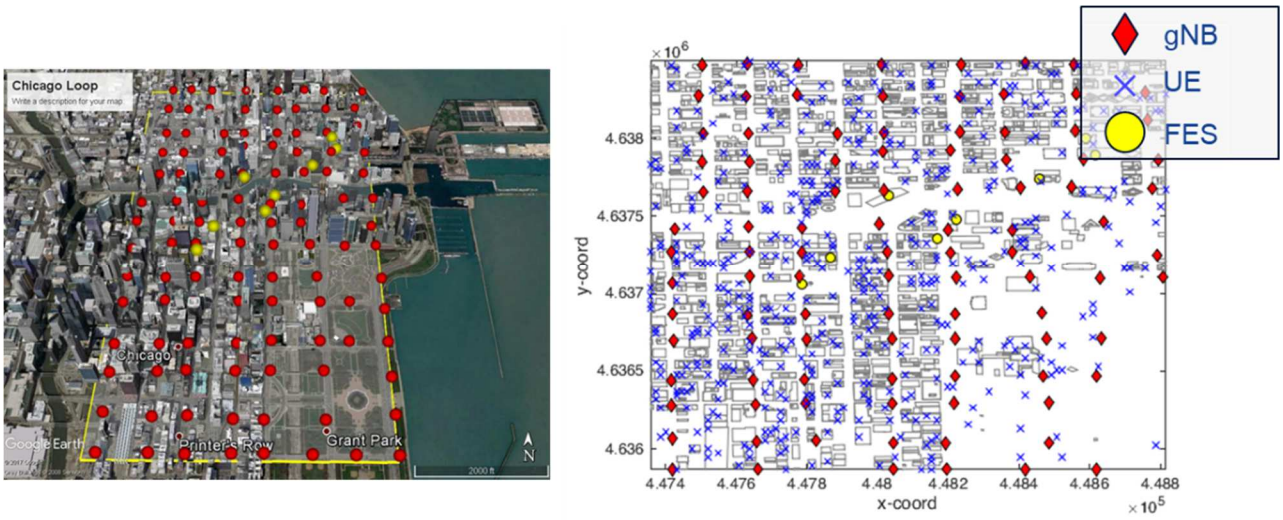

Figure 3. The layout of the network simulator used for evaluating the interference from the 5G system (uplink and downlink) on existing FESs in the Chicago Loop.

Our preliminary study shows that the required exclusion zones around FESs could be a limiting factor for 5G deployments when the 5G and FSS systems are deployed co-channel, especially in dense urban ones where FESs are present. (Other environments such as suburban and rural should also be studied.)

We then studied the impact of density and loading of gNBs as well as uplink power control on the potential interference from 5G into FESs. Our study concludes that co-channel deployment of 5G and FESs could still incur significant interference in close proximity to each other:

- Even when density of gNBs is low
- Even when the gNB load is 25%
- Even when 5G UEs use UL power control. New algorithms are being studied but this will help only the interference from UEs to FESs.

Since co-channel operation of 5G and FSS fixed earth stations in close proximity could be problematic, we studied the case where the two systems are not using the same spectrum blocks. Under our assumptions and deployment scenarios, a guard band of 15 MHz or more between FSS and 5G could maintain the interference to noise ratio at the FES receivers below -6dB. If real-world parameters of the FESs are known, the study could be repeated to determine a more accurate guard band requirement.

Based on the initial coexistence considerations above, Nokia urges the Commission to clear the band of satellite FESs to allow 5G systems to thrive in the band. While doing so, the Commission should also ensure the decreasing use of 3.7-4.2 GHz band by FSS, by placing moratoria on new earth stations and on earth station renewals, unless the earth station applicant shows hat C-band downlink is the only reasonable transmission path. Alternative transmission platforms like fiber could also be encouraged.

While the band is being cleared, the 5G systems could share the spectrum with FSS systems via coordination during a transitional sharing period. "Full-band, full-arc" takes out the entire band at each FES and leaves no spectrum for other users. If up-to-date FES information such as spectrum blocks, azimuth, antenna gains, etc. used by FESs is known, then coordination of 5G with FESs will be easier. Furthermore, as FWCC stated in its Petition to ease coordination of terrestrial and fixed services,[16] frequency coordination with FSS in 3.7-4.2 GHz and 6 GHz is currently slow, cumbersome and needs human intervention. We therefore agree with Broadband Access Coalition[17] that this process could easily be automated leveraging propagation modeling-driven co-existence computations for frequency coordination between FSS and 5G systems.

[16] FWCC Petition.
[17] BAC Petition at 34-35.

We also believe it is feasible for mobile broadband to share the 3.7-4.2 GHz band with fixed point-to-point links via coordination because of the relatively small number of fixed links.

D. Service Rules and Licensing Framework Should Support Robust, Nationwide 5G Network Deployment

a. The Commission Should Implement a Licensing Framework that Supports Widespread Investment

Nokia believes that the 3.7-4.2 GHz band offers the greatest promise in mid-band spectrum for near-term deployment of robust 5G services, based on the combination of available bandwidth and propagation characteristics. While Nokia anticipates the 3.7 GHz band will be the home of bleeding edge communications technologies, the Commission's goal should be for that technology to become widely deployed and available to all. For this reason, we recommend that the Commission enable a licensing framework that supports sustained investment and widespread network deployment.

By analogy, 4G LTE offers amazing new capabilities beyond what most of us could imagine as we began deployment, and the success of 4G was facilitated by proven licensing concepts for widespread deployment. Nokia believes that 10-year or more licensing terms, with expectation of renewal, as well as large license sizes (e.g., CMAs or larger) have led to U.S. leadership in 4G and could similarly facilitate U.S. leadership in 5G deployments. One important difference between 4G deployments to date and 5G deployments to come is the opportunity for bandwidths far larger than those contemplated for 4G. As such, Nokia tentatively recommends that the Commission consider licensing the 3.7 GHz band in 100 MHz blocks to permit wideband services while still facilitating multiple licensees to compete in the band.

b. Transmit Power

Deployment of 5G on bands below 6 GHz will typically make use of Massive MIMO (mMIMO) technology where the radio base stations create directional beams towards the user equipment (UE) delivering multiple streams (layers) of information to multiple subscribers in parallel. This spatial reuse of frequencies enables high spectral efficiency, resulting in greatly increased system capacity. Traditional approaches to transmit power and emissions requirements need some refinement if we are to maximize the benefit of mMIMO technology when deploying 5G in the U.S.

The current low Effective Isotropic Radiated Power ("EIRP") limits for base stations in the CBRS band of 30 dBm/10 MHz for Category A and 47 dBm/10 MHz for Category B should not be adopted for the 3.7-4.2 GHz band. Instead, the Commission should consider higher transmit power similar to other bands like 75dBm/100MHz in the Spectrum Frontiers Report and Order[18] to enable robust and ubiquitous deployment of 5G technologies.

c. Emissions

Extending the approach outlined in KDB 662911 D01 Multiple Transmitter Output v02r01 would significantly disadvantage mMIMO in comparison to the approach used in other parts of the world. In particular, it is likely to increase the power backoff required, impacting product size and cost. Nokia recommends that there should be some upper bound in the MIMO equation (10 log (N) where N is number of antennas) because, as number (N) antennas increases, significantly low emissions levels must be measured below the noise floor. Nokia recommends the Commission align its approach with other regions of the world,

[18] *Use of Spectrum Bands Above 24 GHz for Mobile Radio Service*, GN Docket No. 14-177, FCC 16-89, at ¶ 277 (rel. July 14, 2017).

maximizing product commonality to improve economies of scale, helping drive rapid uptake of 5G to ensure the competitiveness of the U.S. as we enter a new communications era.

Considerable work is ongoing within 3GPP to formulate approaches for establishing mMIMO emissions requirements including measurement methodologies (such as 3GPP specification TS3 8.104, TS 38.141-2, TS 37.105 and TS 37.145-2). As this proceeding progresses, we will update the Commission on the outcome of the work in 3GPP. Nokia urges that the Commission consider the outputs of 3GPP so that the U.S. can leverage the global 5G ecosystem.

IV. TERRESTRIAL MOBILE USE OF THE LOWER 6 GHZ BAND AND UPPER 6 GHZ BAND SHOULD BE EXPLORED WITH CAUTION

Nokia does not oppose the Commission's consideration of additional bands in this NOI, namely the (1) 5.925-6.425 MHz Band; and (2) the 6.425-7.125 GHz band. Nokia further agrees that the Commission appropriately divides the 6 GHz band into its two halves, the upper and lower ranges, which should be considered on their own merits.

The upper and lower 6 GHz bands include relatively modest FSS operations as well as extensive fixed service (FS) terrestrial services. The lower 6 GHz FSS operations support uplink transmissions and are paired with FSS downlink operations in the 3.7-4.2 GHz band, discussed above. With the declining FSS downlinks usage in the 3.7-4.2 GHz band discussed above, it follows that uplinks usage for those FSS systems is also on the decline. The more challenging issue, which is true throughout both the upper and lower portion of the 6 GHz band, is the thriving incumbent fixed service links in the band, comprising many tens of thousands of links. Nokia is a major provider of microwave equipment that supports fixed service links in this band. Far from declining, Nokia anticipates this service will continue to be robust and grow into the future.

Nokia is concerned whether any new services could be introduced into the lower or upper portions of the 6 GHz bands without causing harmful interference into incumbent terrestrial fixed services. Nokia further agrees with the Commission's repeated commitment that any unlicensed operations in the band must protect the FS operations that will continue to operate there.[19] However, it is also critical that the Commission recognize that rigorous engineering analysis of potential interference into incumbent FS operations is required before introducing any new services, including unlicensed services.

While Part 15 rules would legally require unlicensed devices to avoid causing interference to licensed incumbents, such a legal construct is not enough. On this score, the NOI asks very important questions regarding interference mitigation techniques and potential restrictions that would ensure no interference to incumbent FS services.[20] Nokia urges that the Commission continue to build a complete record that demonstrates under what technical parameters, if any, unlicensed mobile operations can coexist in the band without causing harmful interference into FS systems. Moreover, the Commission should continue to separately consider the upper and lower portions of the band, as the record may lead to different conclusions in different parts of the band.

[19] *NOI* at ¶ 29.
[20] *Id.*

V. CONCLUSION

Nokia requests that the Commission proceed to a Notice of Proposed Rulemaking, consistent with the recommendations set forth in these Comments.

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October 2, 2017